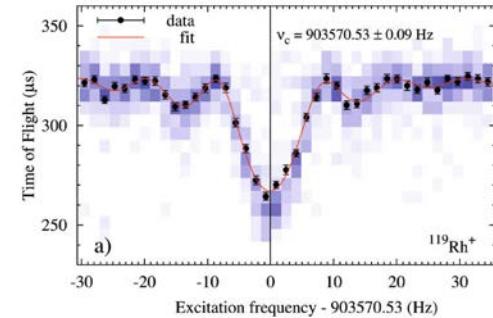
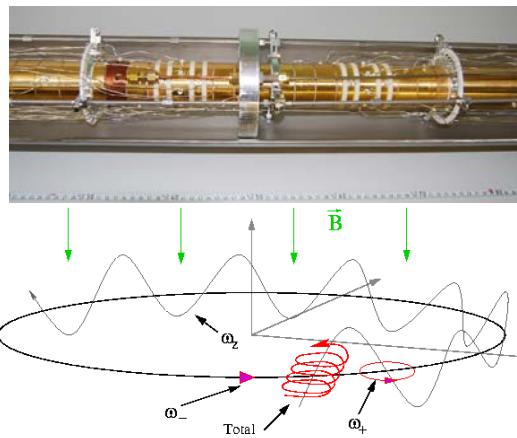


# JYFLTRAP PENNING TRAP – A TOOL TO STUDY ISOMERS FOR NUCLEAR STRUCTURE AND ASTROPHYSICS

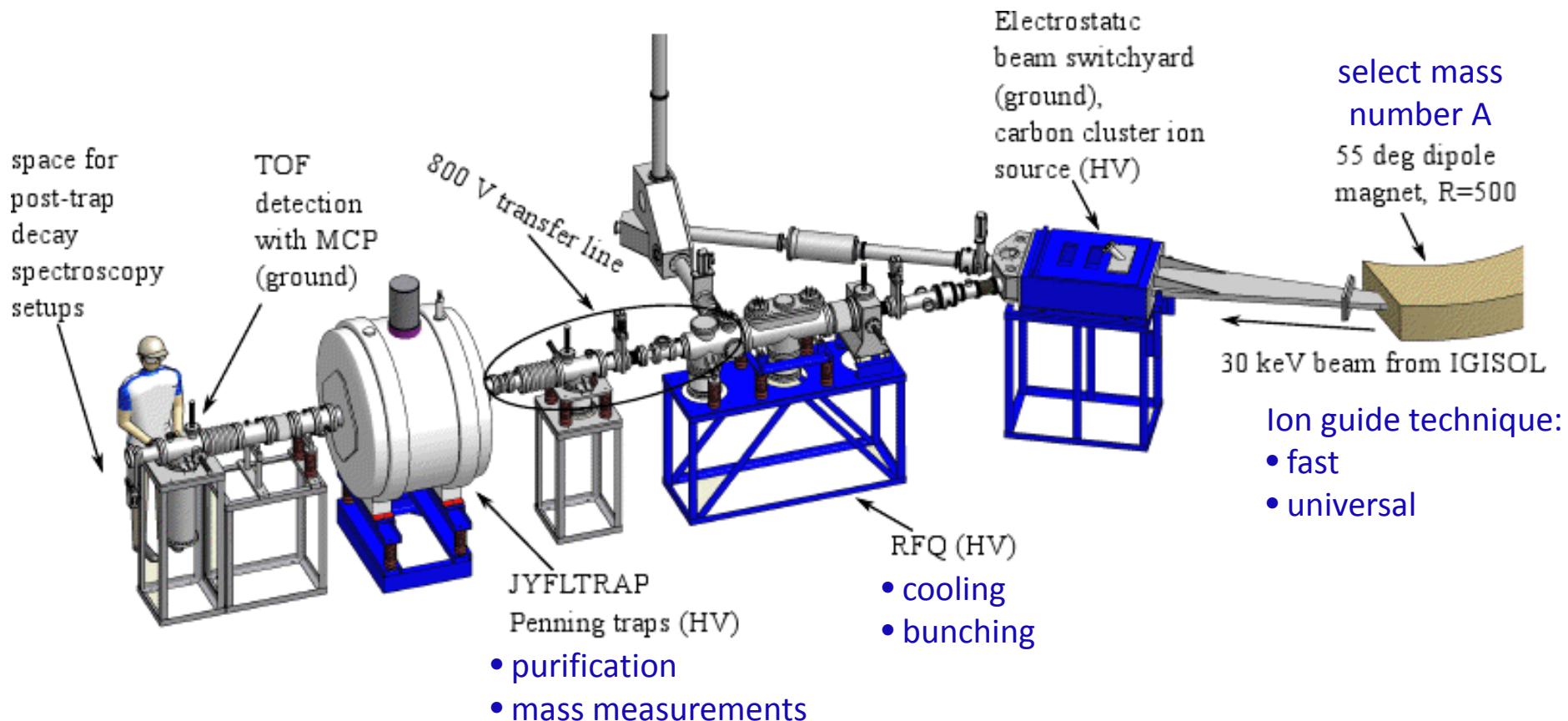
Anu Kankainen, University of Jyväskylä



$$v_c = \frac{qB}{2\pi m}$$



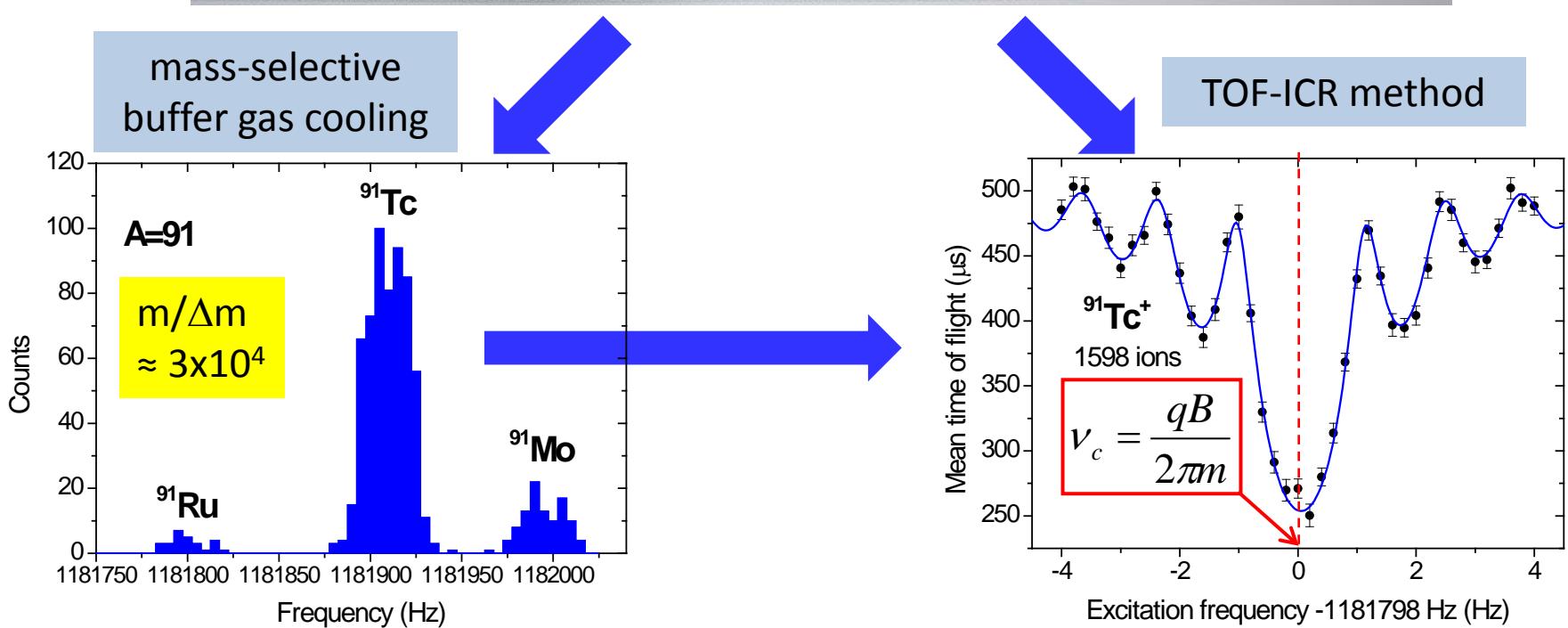
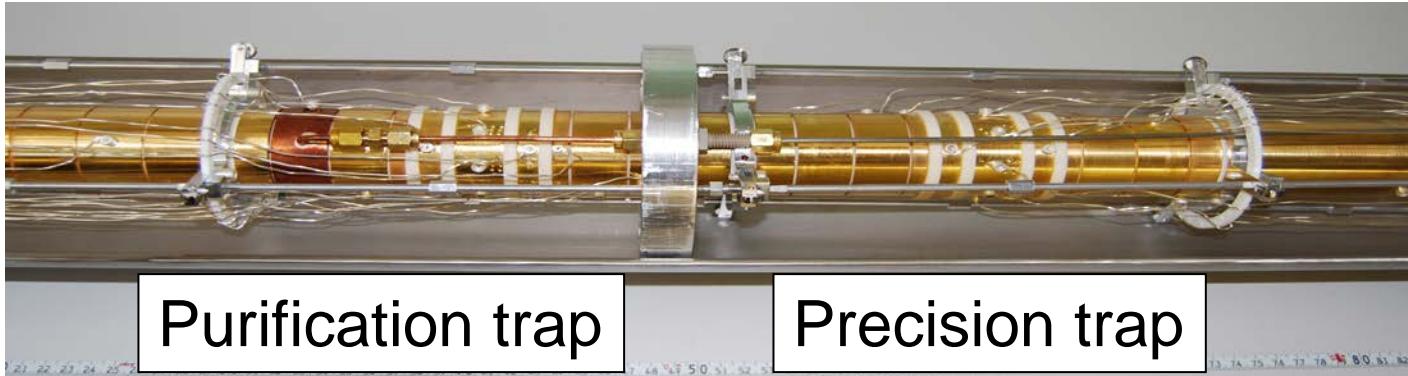
# IGISOL facility



...new IGISOL 2012!



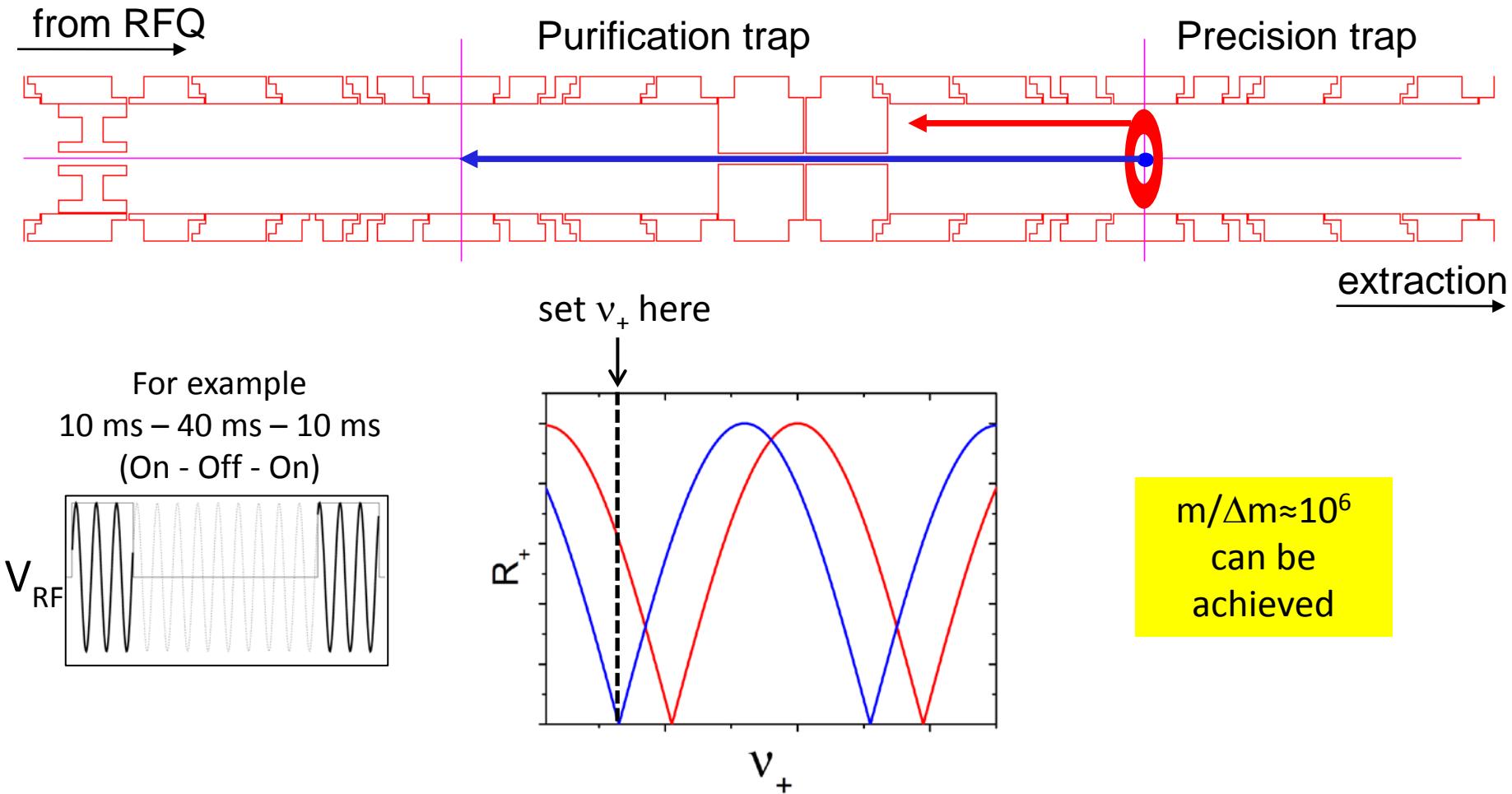
# JYFLTRAP at IGISOL



# Isomeric purification

## DIPOLE RAMSEY CLEANING

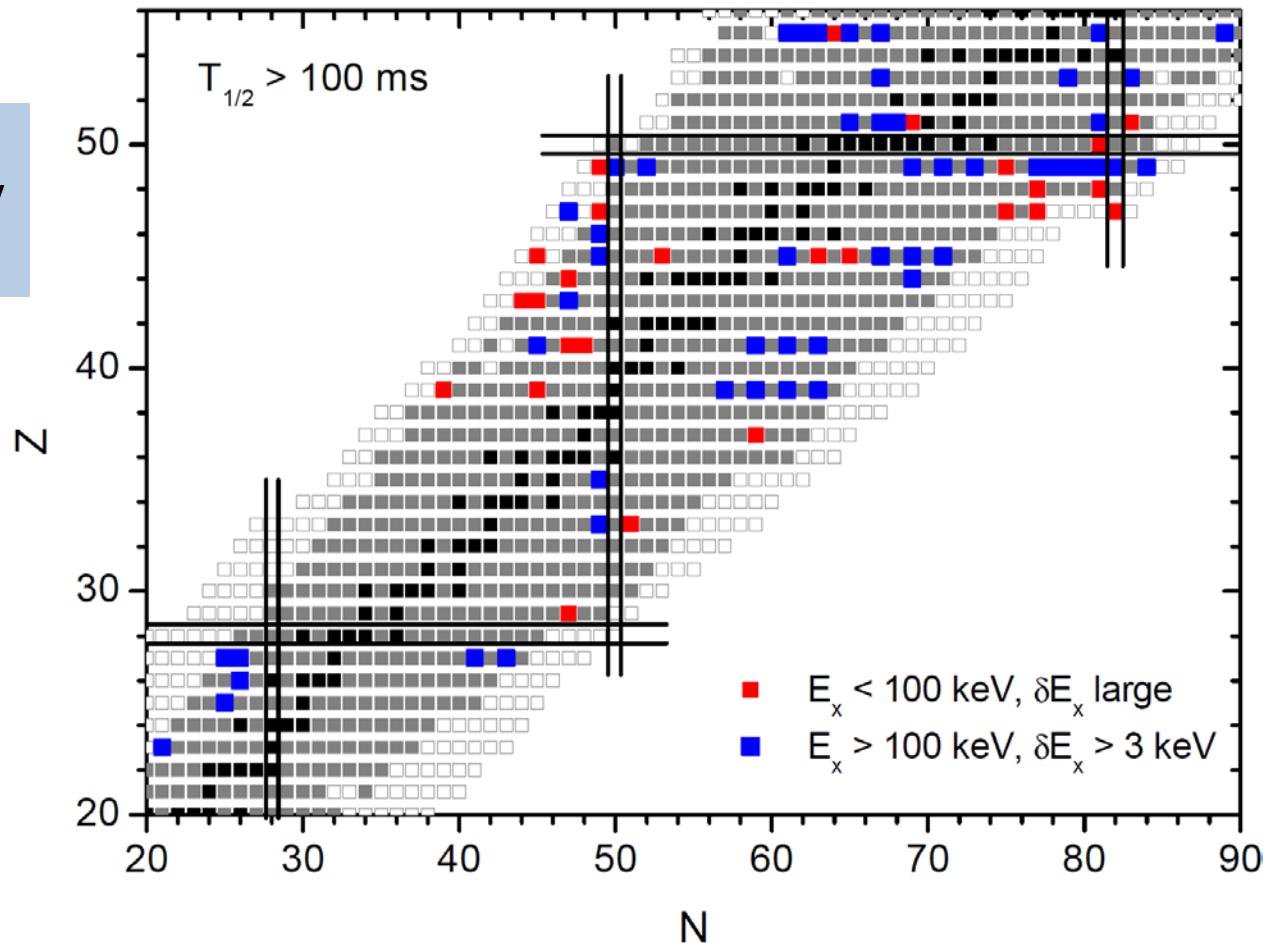
T. Eronen et al.,  
Nucl. Instrum. Methods Phys. Res. B 266 (2008) 4527



# Isomers for Penning traps ? (NUBASE2003)

- Half-life: > 100 ms
- Excitation energy > 100 keV
- Typical precision 3-5 keV

Useful if gamma or conversion electron spectroscopy cannot be applied



# Isomers and nuclear astrophysics

Capture rates depend exponentially on Q-values



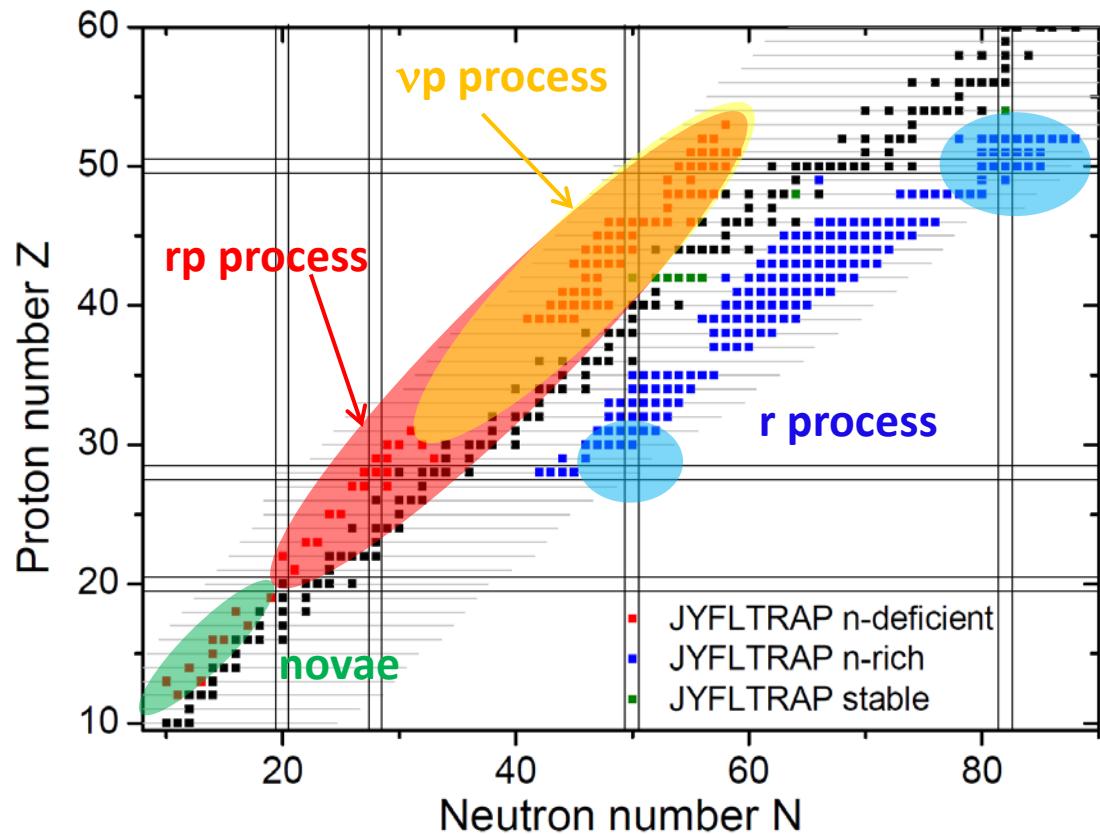
Need **accurate** masses



Identify the measured state!

## Isomers:

- Beta-decay half-lives
- Population of states
  - Capture rates



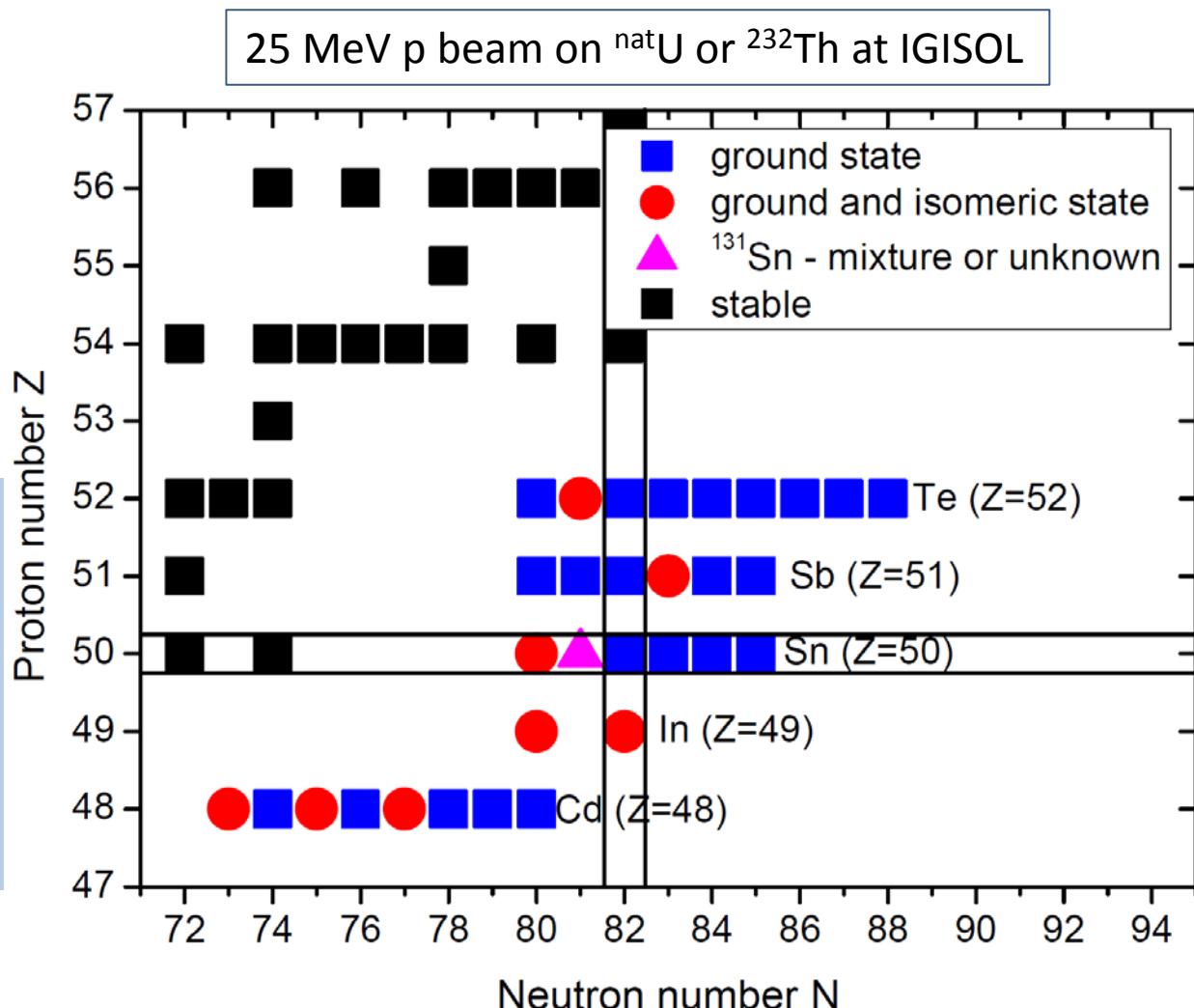
# Region close to $^{132}\text{Sn}$

## Ground states:

J. Hakala et al.,  
*arXiv:1203.0958v2 [nucl-ex]*  
submitted to *Phys. Rev. Lett.*

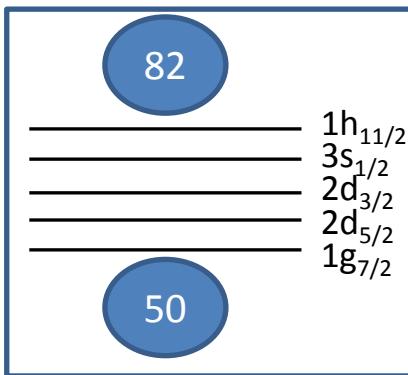
## Isomers:

$^{133}\text{Te}^m$  ( $11/2^-$ )  
 $^{134}\text{Sb}^m$  ( $7^-$ )  
 $^{130}\text{Sn}^m$  ( $7^- \#$ )  
 $^{129}\text{In}^m$ ,  $^{131}\text{In}^m$  ( $1/2^-$ )  
 $^{121}\text{Cd}^m$ ,  $^{123}\text{Cd}^m$ ,  $^{125}\text{Cd}^m$  ( $11/2^-$ )  
+  $^{132}\text{Sb}^m$  ( $8^-$ ) (preliminary)

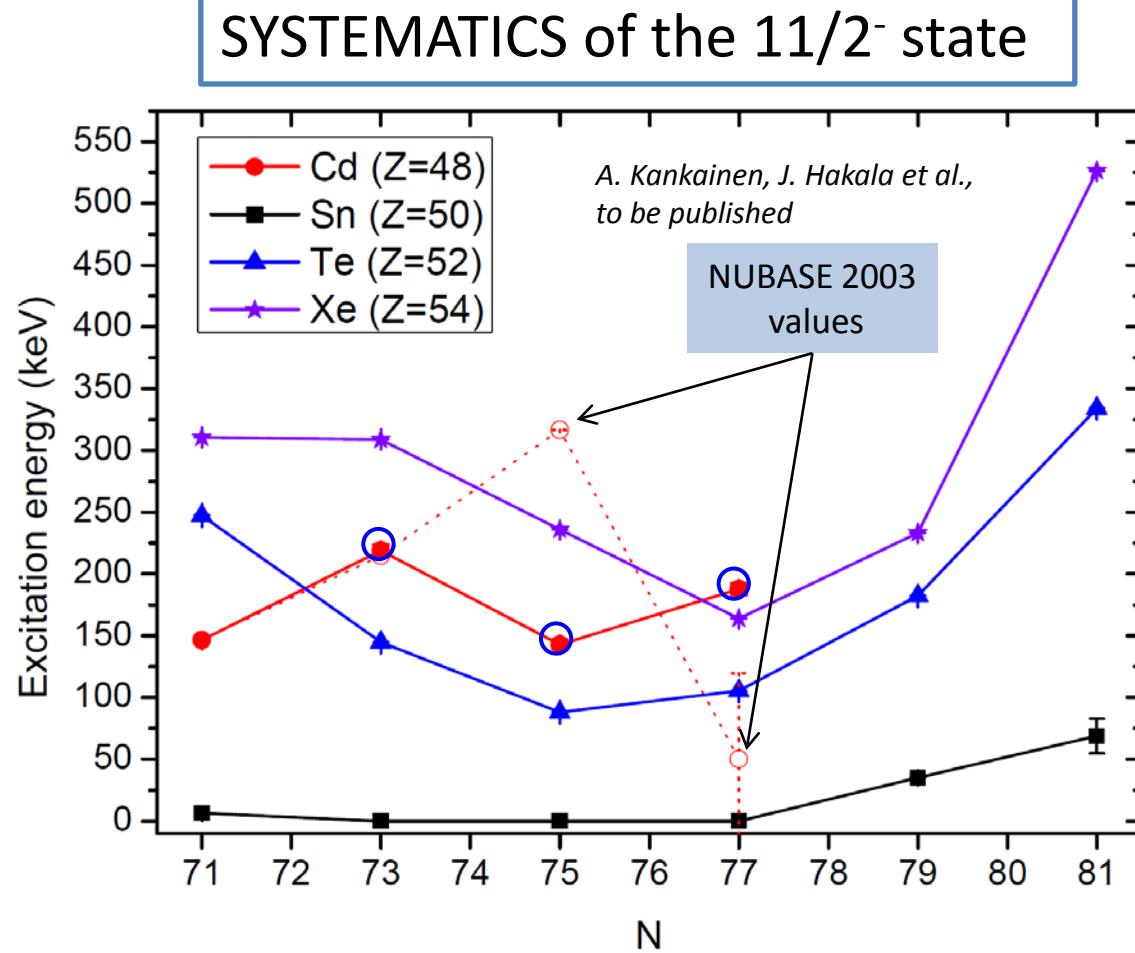


# $11/2^-$ isomers in odd-N isotopes

Odd neutron in  
the  $1h_{11/2}$  shell



JYFLTRAP agrees with  
the literature values  
of the well-known  
isomers in  
 $^{121}\text{Cd}$ ,  $^{130}\text{Sn}$  and  $^{134}\text{Sb}$ .



JYFLTRAP values → similar trend as for Te isotopes

# $^{123}\text{Cd}^m$

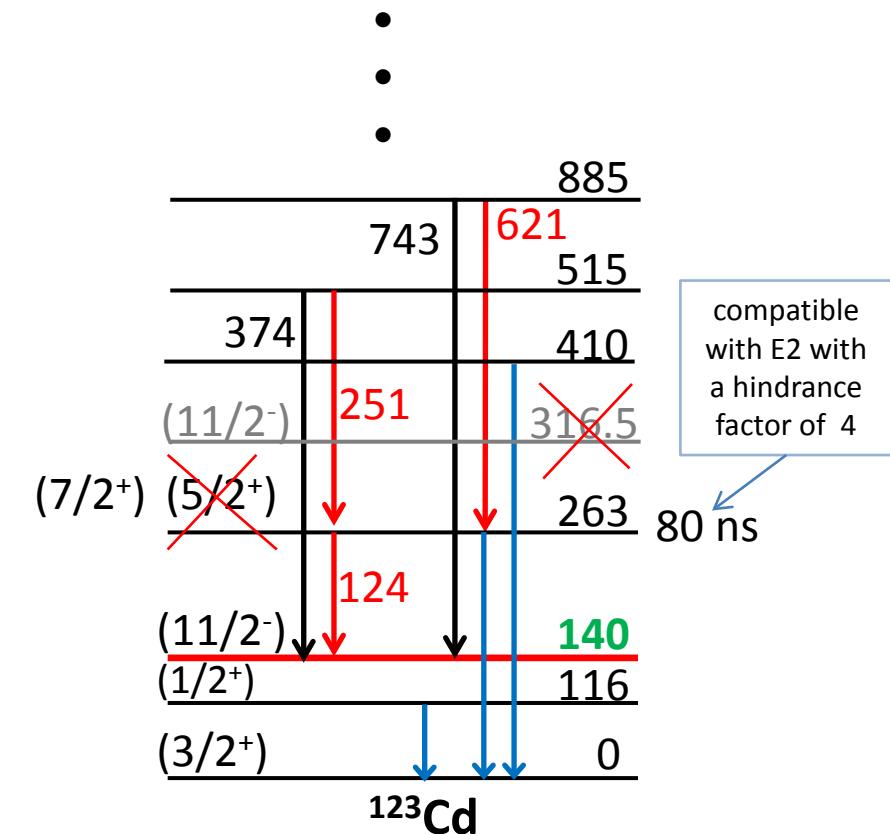
Previously adopted value:  
 $E_x(11/2^-) = 316.52(23)$  keV

H. Huck et al., Phys. Rev. C 40 (1989) 1384

Based on  $\gamma$ -cascade relations  
 following the beta decay of  $^{123}\text{Ag}$ :

- 124 keV  $\gamma$ -transition → isomer
- 116, 264 and 410 keV  $\gamma$ -rays → g.s.
- Maximized the shared levels
- Search range:  $E_x = 260-400$  keV

JYFLTRAP:  $E_x = 144(4)$  keV !!!



The level scheme  
 should be  
 reinvestigated

# $^{123}\text{Cd}$ g.s.

Problems in the determination of the ground-state  $Q_\beta$  value...

TABLE I  
Details and results of the data analysis for the Cd isotopes

L. Spanier et al., NPA 474 (1987) 359

| A   | Spin<br>$J^\pi$ | Gate<br>(MeV) | Level<br>(MeV) | Range of fit<br>(MeV) | E.P. energy <sup>a)</sup><br>(MeV) | Resulting $Q_\beta$ <sup>a)</sup><br>(MeV) |
|-----|-----------------|---------------|----------------|-----------------------|------------------------------------|--|
| 124 | $0^+$           | 0.180         | 0.243          | 2.1–3.7               | 3.924                              | 24   |
| 126 | $0^+$           | 0.428         | 0.688          | 2.1–4.5               | 4.798                              | 19   |
| 128 | $0^+$           | 0.857         | 1.173          | 3.9–5.7               | 5.898                              | 288  |
| 123 | $\frac{3}{2}^+$ | 0.428         | 2.529          | 1.3–3.5               | 3.624                              | 21   |
|     |                 | 1.695         | 2.393          | 1.3–3.5               | 3.590                              | 37   |
|     |                 | 1.831         | 2.529          | 1.3–3.3               | 3.464                              | 59   |
|     |                 | 1.843         | 2.541          | 1.3–3.3               | 3.547                              | 51   |
|     |                 | 2.461         | 2.461          | 1.3–3.5               | 3.710                              | 41   |
|     |                 | 2.602         | 2.602          | 1.3–3.3               | 3.513                              | 36   |
|     |                 |               |                |                       | 6.115                              | 33   |

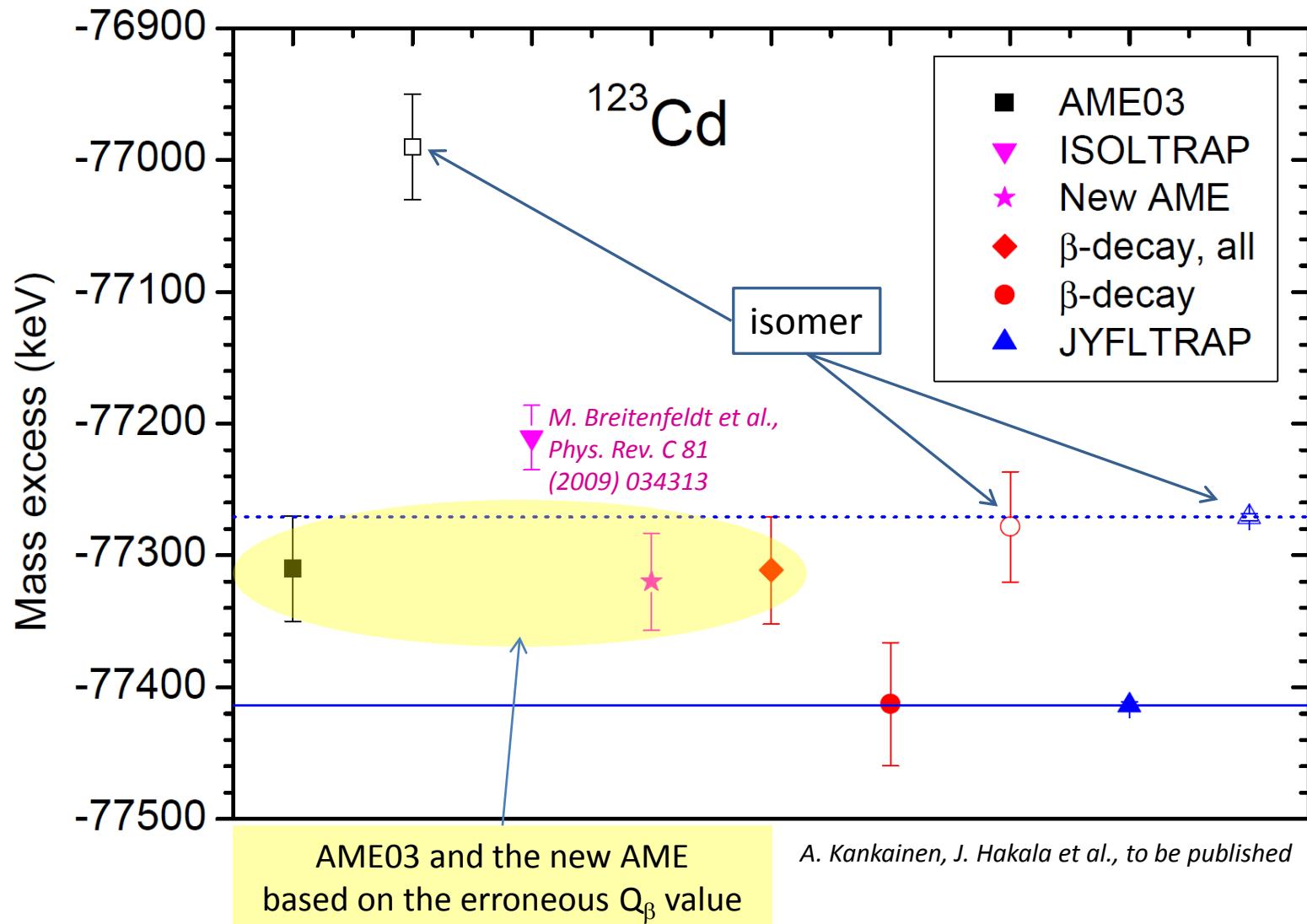
Fed by  $^{123}\text{Cd}^m$   
 $\beta$  decay NOT by  
the ground state!

H. Huck et al., PRC 39 (1989) 997

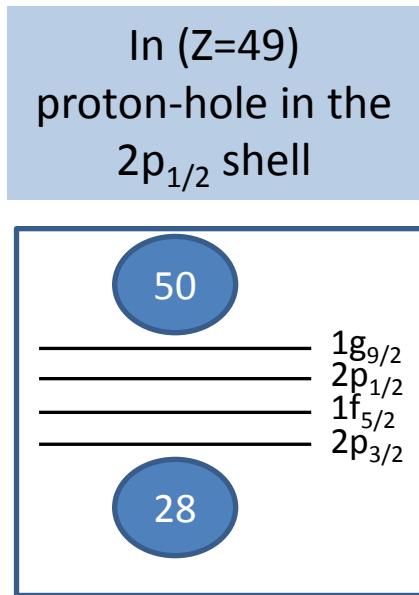
Too high for  
the ground  
state of  $^{123}\text{Cd}$



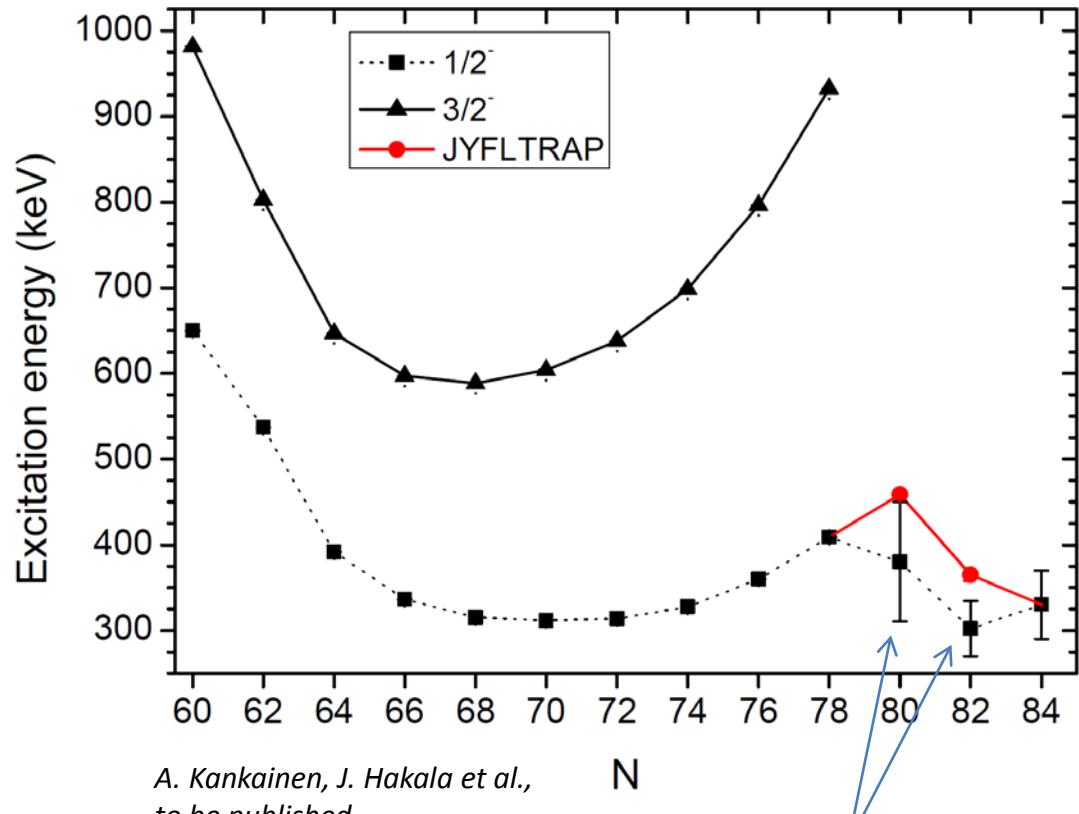
# $^{123}\text{Cd}$ : comparison of results



# $1/2^-$ isomers in In



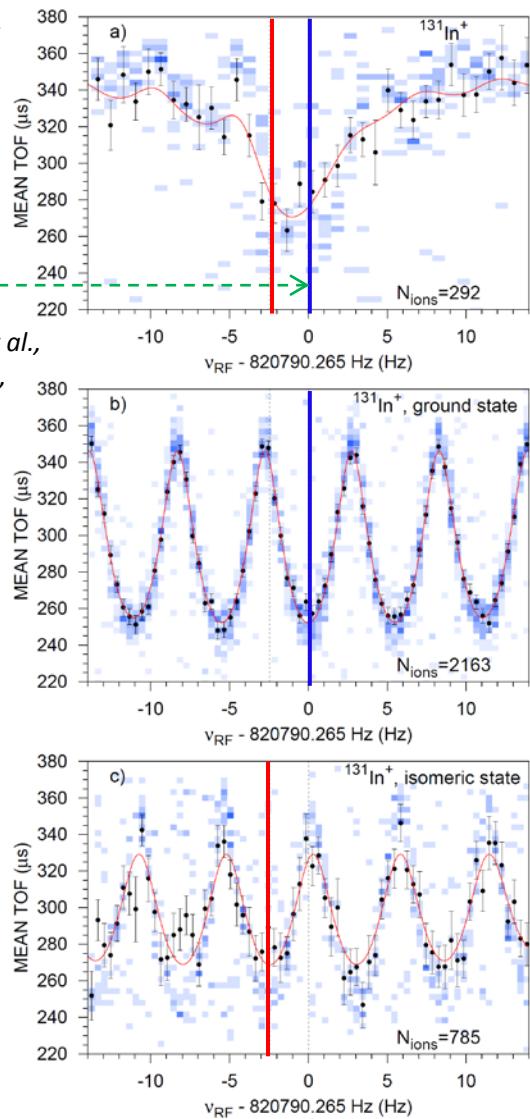
Excitation energy increases from  $N=78$  to  $N=80$



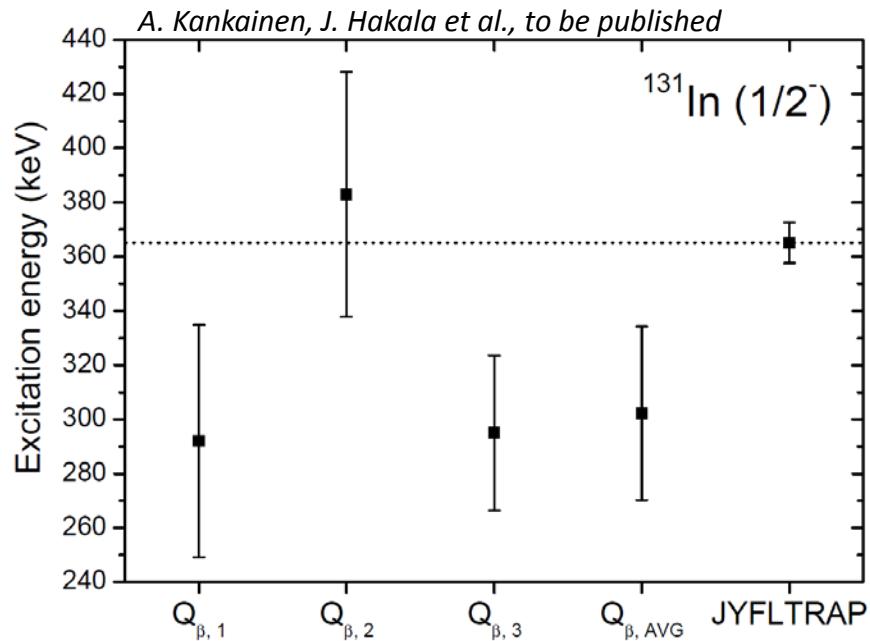
Old values based on beta-  
decay energy differences

# $^{131}\text{In}$

$21/2^+$



- Measured the ground state and the  $1/2^-$  isomer
- $21/2^+$  isomer at 3764(88) keV not scanned



B. Fogelberg et al.,  
Phys. Rev. C 70,  
034312 (2004)

$$E_x = Q_{\beta} [{}^{131}\text{In}^m (1/2^-)] - Q_{\beta} [{}^{131}\text{In} (\text{g.s.})]$$

9524(26) keV

9232(34) keV

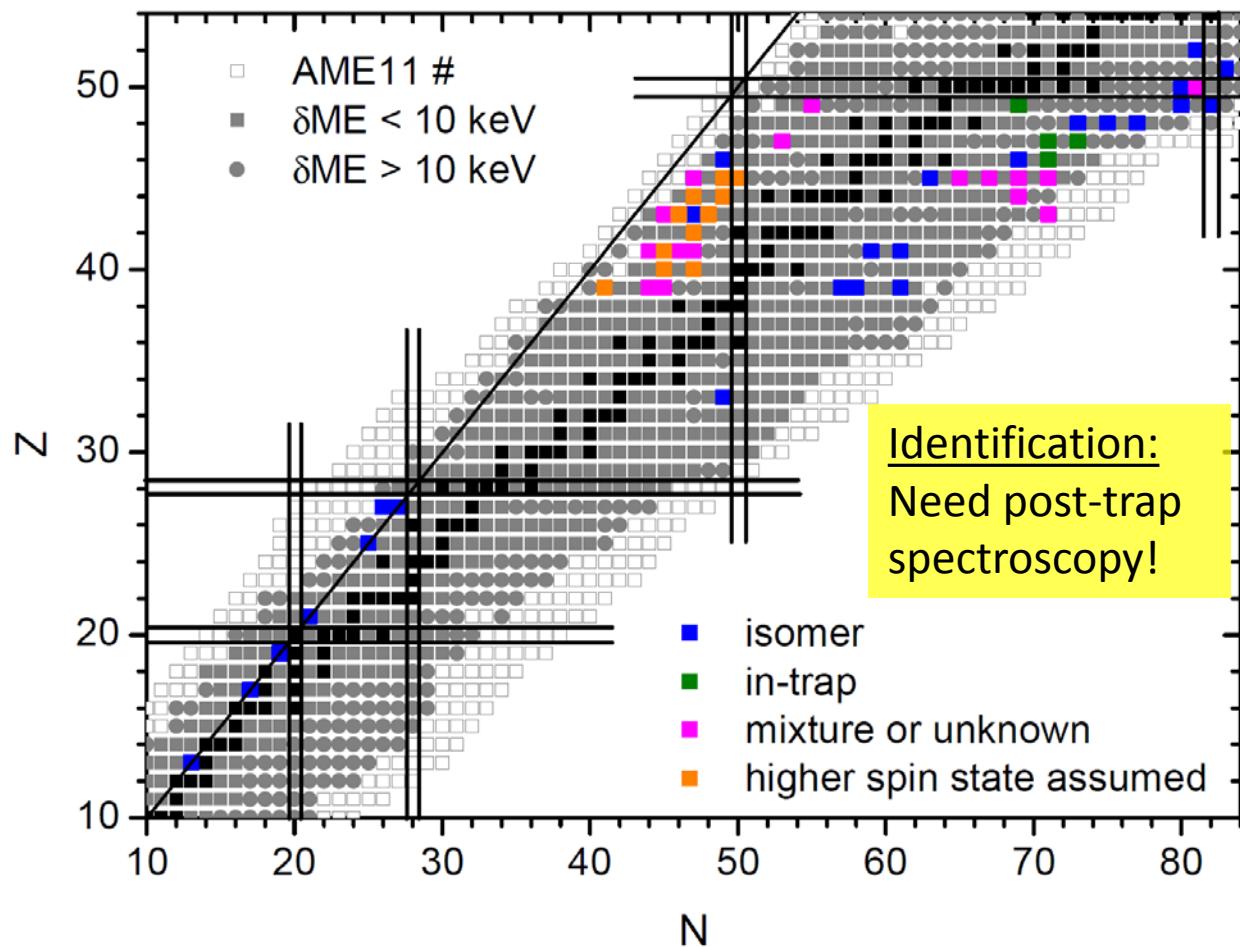
9141(37) keV

9229(12) keV



# Summary

- JYFLTRAP is a useful tool for studying isomers with  $E_x > 100$  keV and  $T_{1/2} > 100$  ms
- Typical precision better than 5 keV
- 25 isomers measured with JYFLTRAP



# Acknowledgements

## IGISOL and JYFLTRAP:

J. Hakala  
D. Gorelov  
A. Jokinen  
V.S. Kolhininen  
I.D. Moore  
H. Penttilä  
S. Rinta-Antila  
V. Sonnenschein  
  
T. Eronen (MPI-K)  
J. Rissanen (LBNL)  
A. Saastamoinen  
(TAMU)  
J. Äystö (Helsinki  
Institute of Physics)



*This work has been supported by the Academy of Finland  
under the Finnish Centre of Excellence Programme 2006–2011  
(Nuclear and Accelerator Based Physics Programme at JYFL).*



# Status of IGISOL4

